

NEONATAL BURNS - A ROMANIAN EXPERIENCE FROM A TERTIARY CARE BURN UNIT

BRÛLURES NÉONATALES: L'EXPÉRIENCE D'UN CTB ROUMAIN

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SUMMARY. Burns in neonates is a unique pathology that poses management challenges, as, besides treating the burn injury, the medical team needs to be familiar with the unique physiology of the newborn. This study aimed to review our center's experience with the management of neonatal burns. A 7-year retrospective study of neonatal burns managed at a tertiary national referral unit in Bucharest, Romania, was performed. Patients were divided into two groups, preterm and term, based on gestational age. Collected data included demographics, treatment, complications and follow-up. Our center managed 13 neonates with burns (5 term and 8 preterm), with a mean age at injury of 8.6 days. All neonatal burns were thermal injuries. For preterm babies, all burns were iatrogenic, consisting of victims of a fire in a Maternity Hospital, while for the term group only one was iatrogenic. Burns were more extensive in the premature group (65% vs. 20% mean TBSA, $p=0.0001$). All premature patients had associated inhalation injuries. Surgical treatment was indicated for two term patients. Survival rate was 77% and was negatively influenced by inhalation injury, burn shock and TBSA >50%. In conclusion, the majority of hospitalized neonatal burns in Romania were the result of a fire disaster secondary to an infrastructure deficiency. Their management is complex, posing specific challenges, and needs to be led by a multidisciplinary team that can ensure an individualized continuum of acute burn care and recovery.

Keywords: neonatal burns, prematurity, fire disaster

RÉSUMÉ. Les brûlures du nouveau-né (NN) posent un problème physiopathologique spécifique, tenant non seulement aux conséquences de la brûlure mais aussi à la physiologie particulière du NN. Cet article décrit notre expérience. Il s'agit d'une étude rétrospective reprenant les 13 NN pris en charge dans un CTB de référence de Bucarest, pour une brûlure survenue en moyenne à 8,6J. Les patients ont été répartis entre prématurés (P,8) et à terme (T,5). Toutes les brûlures étaient thermiques, toutes iatrogènes dans le groupe P, consécutives à un incendie à la maternité quand une seule était iatrogène dans le groupe T. Elles étaient plus étendues dans le groupe P (65% SCT) que dans le groupe T (20%, $p=0,0001$). Tous les P avaient des lésions d'inhalation. Une greffe a été nécessaire pour 2 T. La mortalité était de 23%, influencée par la surface brûlée, l'inhalation et une surface atteinte > 50 %. En conclusion, la plupart des brûlures de NN roumains ayant nécessité une hospitalisation étaient dues à l'incendie d'une maternité à l'architecture déficiente. Leur prise en charge est complexe et spécifique, ce qui nécessite une équipe entraînée, à même de proposer des soins adaptés, de la phase aiguë à la rééducation.

Mots-clés : brûlures néonatales, prématurité, incendie

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Introduction

Burns in neonates is a unique pathology with great impact on both patient and family and on the society as a whole. Neonates are a complex patient category and their management poses a challenge, as the medical team, apart from treating the injury itself, needs to be familiar with the unique physiology of neonates. Particular burn and age-related factors that need to be considered are: immaturity and fragility of the skin, large body surface area relative to weight and scarcity of donor sites for skin grafting, along with the general pathophysiological response of a newborn to the traumatic event.^{1,2}

Although the skin maturation process starts during embryogenesis, the neonatal skin is functionally and structurally still developing at birth. Therefore it represents a deficient barrier, more susceptible to damage, with increased transepidermal water loss, poor thermoregulation, and high permeability for pathogens and toxins.³ The maturation process continues during the first year of life and is dependent on gestational age. In particular, premature babies represent a high risk category, having a thinner stratum corneum and a weaker dermal-epidermal junction.^{3,4}

Due to the rarity of burns in the neonatal age group, the literature is scarce, mainly being represented by case reports and case series. The aim of this paper is to present our institution's experience and outcomes in managing burns in neonatal patients, including the victims of a fire disaster.

Material and methods

The Clinical Emergency Hospital for Children 'Grigore Alexandrescu' (Bucharest, Romania) is the only national tertiary referral institution for pediatric burns. The charts of all neonates (under 30 days of life) who suffered burn injuries and were managed as inpatients over a 7-year period (2010-2016) were retrospectively reviewed. Depending on gestational age (GA), two groups were considered and compared: term (GA ≥ 37 weeks) and preterm (GA < 37 weeks).

Collected data on patient demographics, treat-

ment, complications and follow-up were entered into a Microsoft Excel spreadsheet (Microsoft Office 2020, version 16.41) and GraphPad Prism 9.0.0 software was used for statistical analysis. Categorical variables were reported as number and percentage and continuous variables were displayed as mean and standard deviation (SD) or median and range. A Kaplan-Meier analysis was performed to evaluate the difference in survival between groups and Pearson's correlation coefficient was calculated to assess the relationship between survival or demise and time. For all comparisons, statistical significance was considered at a p-value below 0.05.

Ethical approval was obtained from the Institutional Research and Ethics Committee.

Results

During the studied period, a total of 13 neonates with burns were managed in our center. The demographic data is presented in *Table I*. Statistically significant differences were recorded between the two groups with regards to age, birth weight and weight at admission.

Table I - Demographics

	Term group (n=5)	Preterm group (n=8)	Overall (n=13)	Term vs Preterm P value
Gender (M/F)	1 / 4	5 / 3	6 / 7	ns
Age (days)	15.6 \pm 10.5 (3-29)	3.7 \pm 3.7 (0-11)	8.6 \pm 9.2 (0-29)	0.01
Birth weight (grams)	2900 \pm 450 (2100-3200)	1700 \pm 440 (1000-2290)*	2200 \pm 750 (1000-3200)	0.001
Weight at admission (grams)	3350 \pm 700 (2300-4200)	1980 \pm 640 (1090-3090)	2508 \pm 938 (1090-4200)	0.004

Data are presented as mean \pm SD (range)

*Birth weight was not available for one patient in the preterm group

All the preterm neonates were victims of a hospital fire in 2010 in the Neonatal Unit of a Maternity Hospital in Bucharest. This fire disaster had 11 initial victims, but 3 neonates died at the scene and were excluded from this study. The mean gestational age was 32.4 \pm 0.5 weeks (32-33 weeks). Comorbidities were present only in the premature group and included newborn respiratory distress (n=4), maternal-fetal infections (n=3), cardiac anomalies (n=2), cranial anomalies (n=2) and intrauterine growth restriction (n=2). The same group included two twin pregnancies.

Etiology of burns

All neonatal burns occurred secondary to thermal injuries. No intentional burn injuries were recorded. In the term group, the causes were represented by: contact with a hot object (n=3), open flame (n=1) and scald (n=1). Of these, n=4 were domestic burns and n=1 occurred in-hospital, through contact with the overheated surface of an incubator from the radiating heat of a defective phototherapy lamp. The domestic events occurred in families with a low socio-economic status leading to substandard living conditions.

All burns in the preterm group were iatrogenic, with an identical mechanism, as they were caused by an accidental fire occurring in the confines of a neonatal intensive care unit, which was triggered by a short-circuit in the air conditioning system. This generated a situation with a very high mortality risk, with the neonates being exposed to temperatures above 150 degrees Celsius, for more than 12 minutes. *Fig.1* shows the severity of the event. The neonates were exposed to flame, contact with hot surfaces (incubators), toxic fumes and high concentrations of carbon monoxide.

Total body surface area (TBSA), depth and localization of burn

The TBSA for the entire group was $47.5 \pm 26.2\%$ (range 8-80%). The premature group suffered more extensive burns, with a mean TBSA of $65 \pm 12.3\%$ (range 40-80%), while the mean for the term group was $19.6 \pm 14.5\%$ (range 8-40%). The difference showed statistical significance ($p=0.0001$).

All patients had at least second-degree burns and full thickness burns were encountered in one premature patient. Most patients (92.3%) had burns to multiple body areas, more frequently to the upper and lower limbs (n=12 patients each) and to the head, hands and trunk (n=9 patients each). All premature patients had associated inhalation injuries, which were not encountered in the term group. Detailed data on individual patient demographics, TBSA and burn severity are displayed in *Table II*.

Therapeutic management

The patients were brought to our Emergency Department by transfer from other hospitals in 10 cases,



Fig. 1 - (a,b,c) Images from the site of the fire

while 3 patients were brought from home. The initial management followed the ATLS protocol, including

Table II - Data on demographics, TBSA and burn severity and survival

	Patient	Gender	GA (weeks)	Birth weight (g)	Age at admission (days)	Weight at admission (g)	TBSA (%)	Highest burn depth	Survival
Term group	1	F	38	2100	7	2300	10	IIB	Yes
	2	F	40	3000	18	3340	10	IIA	Yes
	3	M	40	3100	3	3200	30	III	Yes
	4	F	40	3200	21	4200	40	III	Yes
	5	F	40	3100	29	3700	8	IIB	Yes
Preterm group	1	M	33	2200	1	2280	70	IIB	Yes
	2	M	33	1700	1	1800	40	IIB	Yes
	3	F	33	1000	5	1090	60	IIB	Yes
	4	M	32	1660	4	1670	65	IIA	Yes
	5	F	32	1660	4	1950	70	IIB	Yes
	6	M	32	1400	11	1440	60	IIB	No
	7	M	32	2290	0	2550	75	IV	No
	8	F	-	-	-	3090	80	III	no

securing the airway, fluid resuscitation, prevention of burn shock and analgesia. For the victims of the Maternity fire, as their identification bracelets had melted, DNA samples had to be sent from both babies and parents to ensure later identification.

As inhalation injury was present in all preterm babies involved in the fire, management of the airway required intubation on site for 4 patients, one suffering a resuscitated cardiorespiratory arrest. The remaining 4 received humidified high flow O₂. None of the term babies required respiratory support.

Fluid resuscitation was done following Parkland's formula, with added maintenance fluid, aiming for a urinary output of 1-2 ml/kg/h. An initial washout and debridement was performed under general anesthesia to evaluate the extent of the injuries and all patients were admitted to our Neonatal Intensive Care Unit (NICU). Analgesic control was obtained with IV and PR paracetamol and morphine infusions, which were needed especially for the change of dressings.

Early nutrition was initiated, either enterally when tolerated, or parenterally. A total of n=8 patients (n=7 premature babies and n=1 term) received parental nutrition for a mean of 3.2 ± 7.4 days (range 1-27 days), with a gradual transition to enteral feeding.

A total of n=11 patients underwent conservative management, with daily dressings using mainly silver sulfadiazine cream (DermazinTM). Our preferred practice is to use antibiotic ointments, such as BaneocinTM (bacitracin/neomycin) or Kanamycin, for burns involving the face. Other products, such as regenerative serums (Theresienöl) and tulle-gras, were used in selected cases. Surgical treatment was indicated in n=2 patients from the term group. In one case, autografting for burns to the cheek and shoulder was performed on day 5. In another case, escharotomy and autografting of burns to the thigh, calf and hand was done on the 3rd day postburn, followed by excision of new eschars from the temporo-parietal scalp, upper arm and posterolateral thorax with autografting on day 17 postburn.

A multidisciplinary approach involving plastic surgery, emergency medicine, anesthetics, neonatology, pediatric surgery, orthopedics, psychology and occupational health was used to manage these patients.

Length of hospital stay

The hospital length of stay (LOS) for survivors was shorter for the term group with a mean length of 29.2 ± 25.1 days (range 7-67 days), compared with the preterm group that had a mean of 39.4 ± 9.18 days (range 30-51 days). Term babies were transferred from NICU to the ward after a mean of 19 ± 15.6 days (range 1-37 days), while the premature patients were discharged directly from NICU.

Analyzing the cohort based on TBSA and LOS, a positive correlation was found for the survivors, which indicates a linear increase in LOS with the increase of TBSA for both groups. A weak positive correlation was identified for the preterm group, with a correlation coefficient of $R^2=0.10$, potentially due to other comorbidities of prematurity that are known to influence LOS in these patients, while for the term group, the positive correlation was moderate to strong with an $R^2=0.62$. A very strong negative correlation was found between TBSA and time until death ($R^2=0.95$) for the patients that did not survive, showing a decrease in length of survival with the increase of TBSA (Fig. 2).

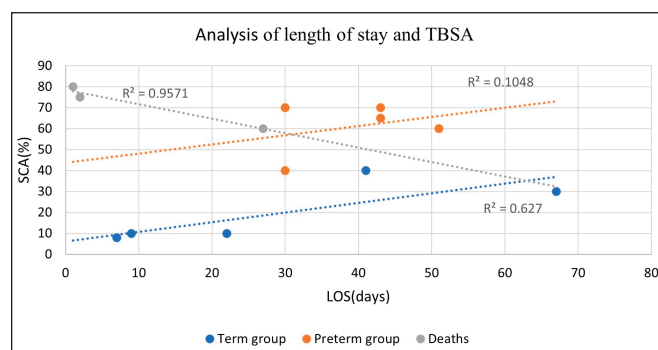


Fig. 2 - Scattered plot graph of LOS and TBSA

Complications

Short-term complications, defined as complications occurring during the inpatient stay, were encountered only in the preterm group and included sepsis (n=1), autoamputation of a distal phalanx (n=1) and seizures (n=1). Long-term complications, occurring after the initial discharge, excluding patients that died, were identified in 2 patients from each group.

In the term group, a patient with 30% TBSA developed keloid scarring over both burn and donor sites with contractures at the left shoulder and arm, requiring scar revision and re-grafting at 3 years follow-up. He also underwent revision of a scalp scar causing alopecia

at 4 years of age. A second patient with 40% TBSA developed keloid scars to the right thigh and buttock and contractures to the right knee and elbow. He required 2 corrective procedures: revision of the right lower limb scars and release of the knee contractures with local flaps at 1 year and 6 months and release of the right elbow contractures with local flaps and grafting at 3 years of age.

In the preterm group, 2 patients had long-term complications and only one required surgical treatment. One patient that had had burns on 65% TBSA developed keloid scarring over the abdomen but without surgical indication. A second patient, with 70% TBSA, had keloid scarring over her flank and abdomen that did not require surgery and retractile scars over the left ulnar border of the hand with ankylosis of the fifth finger requiring correction at 4 years of age.

All patients had been followed-up to complete healing. Healing with minimal scarring was observed for all survivors in the premature group. *Figs. 3-11* show images of the initial burns and the long-term follow-up of selected patients.

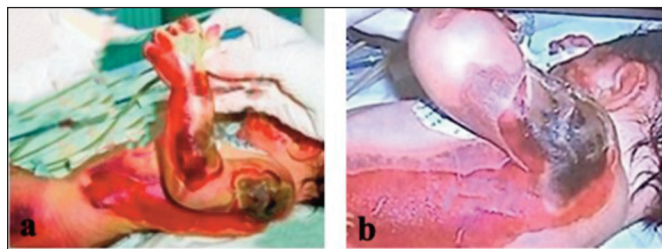


Fig. 3 - (a,b) Patient 3 of term group (see *Table I*) with 2nd and 3rd degree burns to head, chest, abdomen and left upper and lower limb on admission



Fig. 4 - (a,b,c) Long term follow-up of patient 3 in term group after grafting during initial admission and at age of 3 years



Fig. 5 - (a,b) Long term follow-up of patient 3 in term group - scalp burn



Fig. 6 - (a,b) Long term follow-up of patient 3 in term group - cheek burn that had been grafted during initial admission



Fig. 7 - (a,b) Progress during admission of patient 5 in preterm group - 2nd degree burns to chest, abdomen and all limbs



Fig. 8 - (a,b) Long term follow-up of patient 5 in preterm group - abdominal burn at 10 months and 3 years



Fig. 9 - (a,b) Long term follow-up of patient 5 in preterm group - left lower limb burns at 10 months and 3 years



Fig. 10 - (a,b) Long term follow-up of patient 5 in preterm group - left upper limb burns at 10 months and 3 years



Fig. 11 - Patient 4 in preterm group - initial admission 2nd degree burns to lower and upper limbs (a) and long-term follow up of lower limb burn at 3 years (b) and 5 years (c)

Survival and mortality

There were three recorded deaths, all in the preterm group, resulting in a survival rate of 77% for the entire cohort and 62.5% within the preterm

group. The Kaplan-Meier survival analysis is detailed in Fig. 12, the difference in survival between the two groups being statistically significant ($p=0.001$).

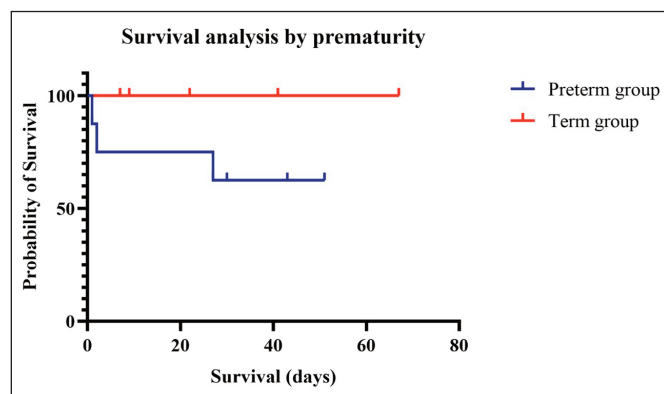


Fig. 12 - Kaplan-Meier survival analysis by prematurity

All deaths occurred in the first month post-injury. One patient that had suffered burns over 80% body surface died on the first day of admission due to a cardiac arrest, on the background of a cardiac malformation. Another patient with burns over 75% of his body surface died on the second day of admission due to a cardiac arrest secondary to burn shock and severe airway burns leading to respiratory failure. The same patient had suffered three resuscitated cardiac arrests. The third patient had suffered burns over 60% of his body surface and died on the 27th day of admission due to cardiac arrest secondary to multiple system organ failure (MSOF). During the admission, he had required pleural drainage for a large effusion, developed seizures that later became intractable, and had multiple resuscitated cardiac arrests.

Survival analysis was found to be negatively influenced by the presence of inhalation injury ($p=0.005$) and by burn shock ($p=0.01$). Also, a dichotomic comparison by burn surface, of burns of less and more than 50% TBSA, showed a significant difference ($p=0.005$), survival being higher for the first group. No statistically significant differences were found for survival by birth weight or gender.

Discussion

Burn injuries are common in children, especially in boys younger than 6 years of age,⁵ but they are rare events in neonates. In the literature, a small number of case series and case reports have been published

of neonatal burns encountered in both domestic and hospital settings. In developed countries, most of the burn injuries occur in a hospital setting, while in developing countries, these are domestic events, mainly due to socio-economic reasons.^{6,7}

A prospective study conducted in a neonatal unit showed that cutaneous injuries were the most common iatrogenic events recorded in neonates (24%), with 5% being classified as severe.⁸ There is a wide range of iatrogenic burn mechanisms described in neonates, from scalds^{9,10} and contact burns from inappropriately used or faulty heating devices (warming bottles, infrared heating lamps, bair huggers, fan heaters)^{6,9,11-16} and medical instruments such as electrocautery pads,⁹ laryngoscope,¹⁷ pulse-oximeters,¹⁸ transilluminator,¹⁹ external cardiac pacing²⁰ and phototherapy lamps,²¹ to chemical burns through antiseptic solutions.^{22,23}

In our series, 69.2% of accidents happened in maternity hospitals, the main cause being infrastructure deficiencies and just one case was related to health care. To the best of our knowledge, this is the first article to report neonatal burns secondary to a collective accident. The domestic accidents were the result of parental negligence in the context of a poor socio-economic status, which is known to be associated with a higher risk of burn injury.²⁴

Because neonates are not ambulatory, child abuse should always be suspected and it has been previously published that the highest rate of non-accidental injury (NAI) occurs in infants younger than 5 months.²⁵ In our series, it was concluded that all the events were unintentional injuries, although in domestic cases parental negligence was suspected.

The collective accident that occurred in the maternity hospital was of an extreme severity, inflicting extensive burns of up to 80% TBSA onto premature infants. The mean TBSA in our entire cohort was 47.5%, significantly higher than other published series. For example, Uguro et al. published a series of 21 neonates with a mean TBSA of 26%,⁷ while Saaq et al. published a series of 11 neonates with a mean TBSA of 18.72%.² Inhalation injury was present in all our preterm neonates, representing 61.5% of patients, while other series reported an incidence of 27.3%² and 38%.⁷ These results suggest that some of the most severe cases of neonatal burns were treated in our clinic.

Although treatment protocols have been established in the pediatric population,²⁶ the management of neonatal burns is still challenging with no clear guidelines. Obtaining adequate resuscitation is one of the difficulties, with the risk of under or over calculation of fluid requirements by the existing formulae.¹ Also, the neonatal liver has a poor ability to store glycogen and release glucose from gluconeogenesis, and thus maintaining normoglycemia can be difficult, requiring the addition of dextrose-containing solutions. Other aspects that have to be appropriately managed in neonates are temperature regulation and pain control. All these aspects, along with the lack of established guidelines, make the multidisciplinary neonatal team approach essential,²⁷ which was very much relied upon in our series as well.

Management is usually based on the local experience. Based on ours, we recommend that in this age group, whenever possible, conservative management should be opted for, as, beside a small total body surface allowing for limited grafting options, these patients have associated comorbidities, and a surgical intervention would be an additional stress factor. As such, topical treatments like silver sulfadiazine,^{9,27,28} silver impregnated antimicrobial dressings such as Acticoat^{TM29} and even enzymatic debridement with collagenase applications³⁰ are reported as an important part of management. We also used DermazinTM in conjunction with other topical applications like antibiotic ointments and tulle gras for the conservative management of burns, with a case-by-case selection.

When surgical treatment is required, the coverage of wounds can be obtained using either skin replacement or skin substitutes.²⁶ Autografting is the current standard of care, but when there is paucity of donor areas, allograft or other substitutes such as amniotic membrane, xenografts or dermal regeneration matrices can be used.²⁶ In selected cases, other surgical options may be employed, such as excision and W-plasty, which was reported in a neonate with full thickness electrical burns from an external cardiac pacing pad.²⁰ In our series, surgical treatment for burns was needed exclusively in term babies, with 2 patients requiring skin autografts.

Mortality rate in our institution was 33% and was

comparable to other case series, in which it was reported at 27.2%² and 43.5%.⁷ As observed previously by Barrow et al., our study also showed that inhalation injury caused a significant increase in mortality.³¹

Follow-up showed that long-term complications were encountered in both groups, in 2 patients each. In the term group, both patients required ongoing management for residual scarring with 2 complex procedures each, while in the premature group only one patient underwent correction of a finger contracture. Clinical observation of healing in our cohort showed that premature newborns had better healing with lesser scars and lesser need for surgery compared to term babies, despite suffering more extensive burns. These results point to the need to explore the regenerative properties of fetal tissues and the hypothesis that premature babies may retain some of these properties in their healing process.³² This process seems to rely on a dampened inflammatory response, a different profile of growth factors and cell mediators, a different gene expression and a more active involvement of stem cells, but the precise mechanisms remain unclear.³³⁻³⁵ Regenerative healing peaks in the second trimester of pregnancy and then gradually passes a transition phase through the third trimester.^{36,37} As our premature patients were neonates with gestational ages of 32-33 weeks, and given the clinical results with long term follow-up, we can infer that the above theory may apply.

Hohlfeld et al. developed fetal skin constructs and used them to treat second and third degree burns, obtaining high quality wound closure without the need for grafting. It was suggested that fetal cells have a role in healing wounds through their promoting effect on adhesion, proliferation and migration of existing cells.³⁸ However, this would need to be investigated through further clinical studies, as it may lead to new therapeutic strategies and to better cosmetic and functional outcomes.

Conclusions

Neonatal burns are rare occurrences that have a major impact on both patient and family, and also on medical systems. In our center the majority of burns

were iatrogenic in nature and were the result of a collective accident. A mass casualty event, such as the burn disaster included in this paper, represents a significant stressor on the healthcare system and served to underline the preexisting issues with some hospitals' infrastructure in Romania. Transfer to a specialized burn unit, fully equipped and with pre-established burn expertise, ensured optimal results for all patients included in this study. Their management is complex, posing specific challenges, and needs to be led by a multidisciplinary team that can ensure an individualized continuum of acute burn care and recovery.

Limitations

The present study has several limitations. It is a retrospective analysis in which the data was collected by chart review and the accuracy is thus dependent on the quality of patient record keeping. Another limitation is the fact that it is a single center observational study of a small sample size. Given the rarity of the pathology, we consider that a multicenter prospective study would be beneficial to objectively evaluating healing of these patients and to developing a universally accepted management protocol.

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